D5-13424

FINAL TECHNICAL REPORT PROTOTYPE 20 WATT SOLID-STATE TELEMETRY TRANSMITTER

VOLUME I OF III

April 1, 1968

THE BOEING COMPANY - SPACE DIVISION

DOCUMENT NO. D5-13424 VOLUME I OF III

TITLE FINAL TECHNICAL REPORT - PROTOTYPE 20 WATT, SOLID-STATE TELEMETRY TRANSMITTER

MODEL NO. CONTRACT NO. NAS8-20777

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TELEMETRY SYSTEMS

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ABSTRACT AND LIST OF KEY WORDS

This document constitutes the technical report for a 20 Watt Solid-State Telemetry Transmitter developed under Contract NAS8-20777 for the National Aeronautics and Space Administration, G. C. Marshall Space Flight Center. The document is organized as follows:

Volume I	Summary Technical Report
Volume II	Test Procedures and Results
Volume III	Operating and Maintenance Instructions

Transmitter
Solid State
S-Band
Varactor
Frequency Multiplier
Power Amplifier
Voltage-Controlled Oscillator (VCO)
Strip Line
Crystal-Controlled Oscillator
Exciter
Modulator
Frequency Modulation (FM)

CONTENTS

ILLUSTRATIONS

TABLES

SECTION 1

INTRODUCTION

1.0 GENERAL

This volume of Document D5-13424 contains a delineation in summary form of the design goals and requirements for the development of a prototype 20-watt, solid-state, ultra high frequency telemetry transmitter. This effort was accomplished for the George C. Marshall Space Flight Center under NASA Contract NAS8-20777.

The results of the test program are summarized in the form of graphs and plots in Section 2. Several conclusions and recommendations based upon the results of the design effort and the test program are given in Section 3.

1.1 DESIGN GOALS AND REQUIREMENTS

The design of the transmitter is based upon NASA/MSFC specification 110158. The performance and product characteristics for the transmitter are listed below:

1.1.1 Electrical

1.1.2 Prime Power Source

The transmitter shall be capable of meeting all the performance requirements specified herein when energized by a prime power source of 28 $\pm$ 4 Vdc, with an impedance not greater than 1 ohm.

1.1.3 Warm-Up Time

The transmitter shall meet all the requirements of this specification within 3 minutes after power has been applied.

1.1.4 Efficiency

The overall dc to RF conversion efficiency shall be at least 10 percent with no more than 8 amps total current.

1.1.5 Output Frequency

The transmitter shall provide an output frequency of 2277.500000 MHz.

1.1.6 Frequency Stability

Variation in the transmitter carrier frequency shall not exceed plus or minus 0.005 percent of the assigned carrier frequency.

1.1.7 Output Power

The minimum output power of the transmitter shall be 20 watts when the transmitter is terminated into a nominal 50-ohm load having a VSWR less than 1.8 at any phase angle.

1.1.8 Modulation Input Impedance

The modulation input impedance of the transmitter shall be 10,000 ohms or greater over the frequency range of 0 to 200 KHz.

1.1.9 Modulation Distortion

When the transmitter is modulated with a peak deviation of 125 KHz, its demodulated output shall contain second and third harmonics of the modulation frequency which are respectively 35 db and 45 db, or greater, below the output level of the corresponding modulation frequency from 300 Hz to 100 KHz.

1.1.10 Intermodulation Distortion

When the transmitter is modulated by two subcarriers of equal amplitude and specified frequencies, the transmitter demodulated output sum and difference subcarrier frequencies shall be 40 db or greater, below each subcarrier level.

1.1.11 Deviation Sensitivity

The deviation sensitivity of the transmitter shall be 200 ± 10 KHz per volt rms or 1.414 volts peak. A positive voltage excursion of the modulation signal shall produce an increase in carrier frequency. A negative voltage excursion of the modulation signal shall produce a decrease in carrier frequency.

1.1.12 Deviation Linearity

The AC deviation linearity of the transmitter shall be within plus or minus one percent of the best straight line approximation for 125 KHz peak deviation and within plus or minus two percent for 500 KHz peak deviation at modulation frequencies from 0 to 100 KHz.

1.1.13 Carrier Deviation

The transmitter shall be capable of being deviated from carrier frequency at least plus and minus 500 KHz.

1.1.14 Frequency Response

The transmitter frequency response shall be flat within plus or minus 1.5 db with respect to 50 KHz modulation frequency, at modulation frequencies from zero to 500 KHz.

1.1.15 Incidental Frequency Modulation

The transmitter incidental frequency modulation shall not be greater than 8 KHz peak-to-peak.

1.1.16 Incidental Amplitude Modulation

The transmitter incidental amplitude modulation shall not be greater than 5 percent.

1.1.17 Open Circuit, Short Circuit Protection

The transmitter shall not be damaged nor shall its performance be impaired when subjected to open circuit and short circuit conditions on the output for a period of 15 minutes.

1.1.18 Reliability

The transmitter shall have a minimum mean time between failure of 10,000 hours and be capable of cyclic operation with a minimum of 330 20-minute cycles, 10 minutes "on" and 10 minutes "off". The transmitter shall have a minimum mean life of 3000 hours.

1.1.19 Polarity Reversal

Reversal of the 28.0 VDC input power source leads shall not damage the transmitter.

1.1.20 Modulation Overload Protection

The transmitter shall not be damaged nor its performance degraded after $\pm$ 28.0 VDC is applied to the modulation input.

1.2 ENVIRONMENTAL

1.2.1 Thermal Shock

The transmitter shall not be damaged nor shall its performance be impaired by exposure to abrupt temperature changes of minus 20° to plus 75°C within a period of not less than 2.5 nor more than 4.0 minutes and plus 75°C to minus 20°C in the same time interval.

1.2.2 Temperature Cycling

The transmitter shall not be damaged nor shall its performance be impaired by exposure to gradually applied temperatures from minus 20°C to plus 75°C.

1.2.3 Moisture Resistance

The transmitter shall not be damaged nor shall its performance be impaired by exposure to a relative humidity of 95 percent with temperatures from minus 20°C to plus 70°C.

1.2.4 Acceleration

The transmitter shall not be damaged nor shall its performance be impaired when subjected to an acceleration of 50 g.

1.2.5 Altitude

The transmitter shall not be damaged nor shall its performance be impaired when subjected to a reduced barometric pressure of 10^{-4} mm of mercury.

1.2.6 Shock

The transmitter shall not be damaged nor shall its performance be impaired when subjected to a half sine wave shock acceleration of 50 g for 11 plus or minus 1 msec.

1.2.7 Vibration

1.2.7.1 Sine Wave

The transmitter shall not be damaged nor shall its performance be impaired when subjected to vibrations from 10 to 2,000 Hz at 20 g peak amplitude.

1.2.7.2 Random Motion

The transmitter shall not be damaged nor shall its performance be impaired when subjected to random motion of 20 g rms for 5 minutes.

1.2.8 Radio Frequency Interference

The transmitter shall not generate nor be susceptible to RFI when tested in accordance with the applicable paragraphs of Specification MIL-I-6181D.

1.2.9 Thermal Vacuum

The transmitter shall neither be damaged nor shall its performance be impaired when subjected to the conditions of 5.2.7 of 50M71810.

1.2.10 Acoustical Noise

The transmitter shall neither be damaged nor shall its performance be impaired when subjected to the conditions of 5.2.4 of 50M71810.

In addition to the above electrical and environmental requirements, the allowable maximum weight of the transmitter is set at 12 pounds.

SECTION 2

TEST RESULTS - SUMMARY

2.0 GENERAL

This section contains the summary of the results obtained from the test program specified in Volume II, Section 1 of this document. The original data sheets and test equipment list are contained in Section 2 of Vol-II and were typed for this section for convenience.

The test program as specified in Volume II was not performed in its entirety. The actual tests monitored by Boeing Quality Control were limited to those tests contained in paragraphs 1.3.2.1 (a) and (b) through 1.3.2.12. Informal tests, without Quality Control observation, were conducted for pressure leakage, automatic level control performance and RFI line conducted, audio frequency susceptibility.

The environmental tests were not conducted. The base temperature of the transmitter was maintained at approximately 22-5°C for all tests.

In general, the transmitter met the requirements of all the tests conducted with the exception of power output for a supply voltage of 24 volts, dc to RF efficiency at a supply voltage of 32 volts, and the RFI audio susceptibility test.

Because of the large drop in power output at a supply voltage setting of 24 volts, all tests were conducted with a minimum supply voltage of 25.5 volts.

2.1 Test Summary

The following is a brief discussion and summary of the results obtained from the tests which were conducted. The referenced paragraph numbers refer to the data sheets and the paragraph of the test procedure of Volume II.

2.1.1 Ground Isolation (Test Paragraph 1.3.2.1.B)

The isolation between grounds was 100 megohms or more. The requirement was for at least 10 megaohms.

2.1.2 Pressurization (Test Paragraph 1.3.2.1.C)

The unit was pressurized for a 24 hour period. The initial pressure was 21.10 psig, and at the end of the test it had dropped to 20.54 psig. This test was conducted by engineering and was not monitored by quality control.

2.1.3 Output Power, Frequency Stability, and DC-RF Efficiency (Test Paragraph 1.3.2.2)

Current, frequency, power output and efficiency were all within requirements for this test except with a 32 volt supply input the efficiency dropped below the 10% requirement to 8.95% and with a 25 volt supply input efficiency was 9.22% and the output power 16.8 watts (20 watts required). The test data is shown in Figure 2-1.

2.1.4 Warm-Up Time (Test Paragraph 1.3.2.3)

The transmitter satisfied this test requirement. The unit was denergized for a 12 hour period and had a base temperature of approximately 16°C at the start of the test. The data is shown in Figure 2-2.

2.1.5 Input Impedance (Test Paragraph 1.3.2.4)

The modulation input impedance was within requirements (10,000 ohms or greater) from dc to 200 KHz. The AC input impedance data is shown in Figure 2-3.

2.1.6 Deviation Sensitivity (Test Paragraph 1.3.2.5)

Both the ac and dc deviation sensitivity were within the requirements of 200 ± 10 KHz per 1 volt rms or 1.414 volt peak. A positive voltage caused an increase in frequency and a negative voltage caused a decrease in frequency.

2.1.7 Deviation Linearity (Test Paragraph 1.3.2.6)

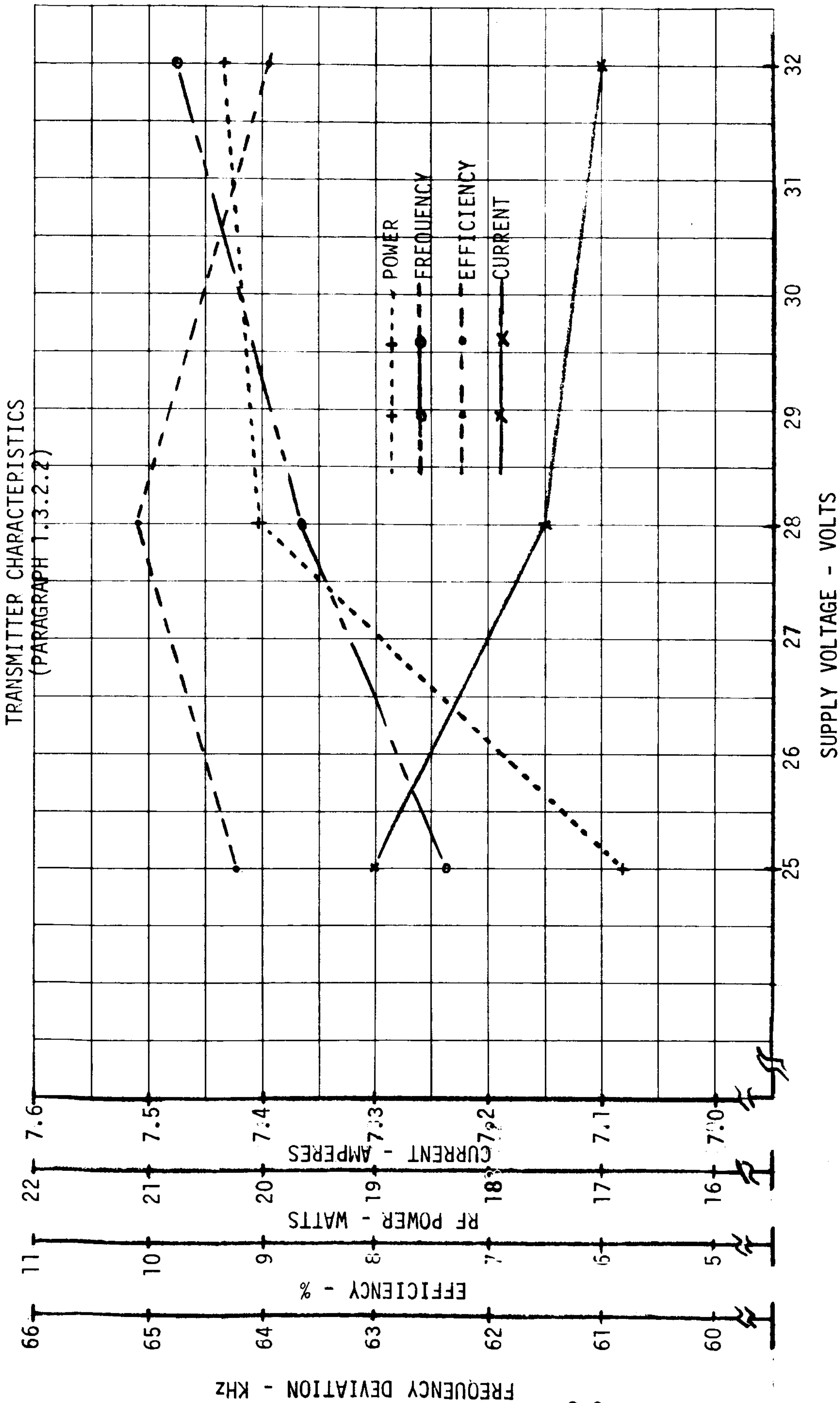
The deviation linearity was well within requirements for both the 125 KHz and 500 KHz deviations. The test results are shown in Figure 2-4.

2.1.8 Frequency Response (Test Paragraph 1.3.2.7)

The frequency response of the unit was within requirements (± 1.5 db) to 470 KHz (500 KHz required). The test data are shown in Figure 2-5. This data has not been corrected or compensated for test system response, i.e. data includes receiver and meter frequency response and thus may be better than that shown. Tests earlier in the week indicated the response at 500 KHz would be in the order of 0.5-1.0 db down.

2.1.9 Incidental Frequency Modulation (Test Paragraph 1.3.2.8)

The transmitter incidental FM was measured to be 6.4 KHz including receiver noise and incidental FM. The measurement technique led eliminated ripple signals inherent in the receiver output. The above data did not include any environmental effects.



TRANSMITTER CHARACTERISTICS
(PARAGRAPH 1.3.2.2)
POWER
FREQUENCY
EFFICIENCY
CURRENT
SUPPLY VOLTAGE - VOLTS
25
26
27
28
29
30
31
32
CURRENT - AMPERES
7.6
7.5
7.4
7.3
7.2
7.1
7.0
RF POWER - WATTS
22
21
20
19
18
17
16
EFFICIENCY - %
11
10
9
8
7
6
5
FREQUENCY DEVIATION - KHZ
66
65
64
63
62
61
60

FIGURE 2-1

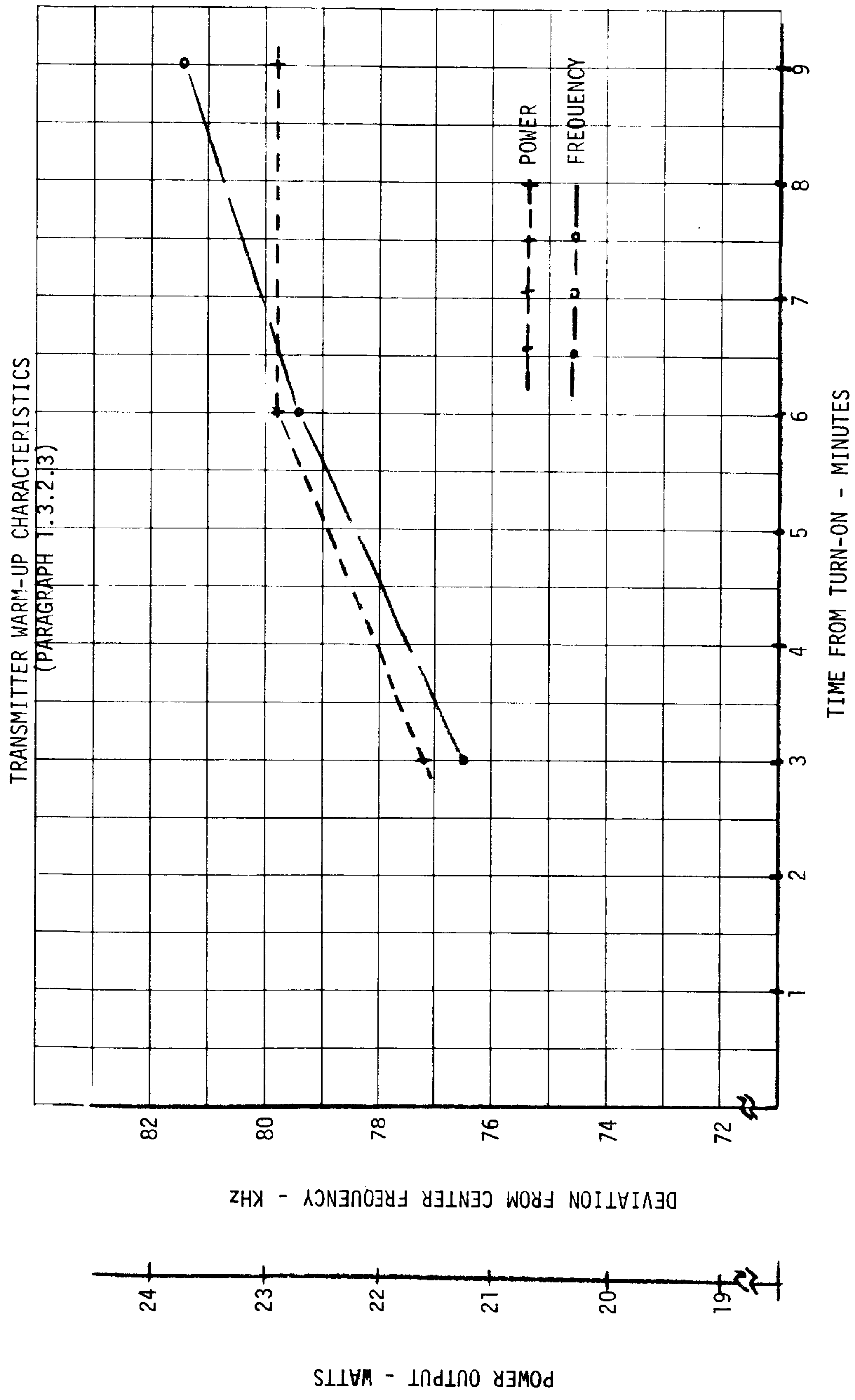

TRANSMITTER WARM-UP CHARACTERISTICS
(PARAGRAPH 1.3.2.3)
POWER
FREQUENCY
TIME FROM TURN-ON - MINUTES
1
2
3
4
5
6
7
8
9
82
80
78
76
74
72
DEVIATION FROM CENTER FREQUENCY - KHz
24
23
22
21
20
19
POWER OUTPUT - WATTS

FIGURE 2-2

AC INPUT IMPEDANCE
(PARAGRAPH 1.3.2.4.2)

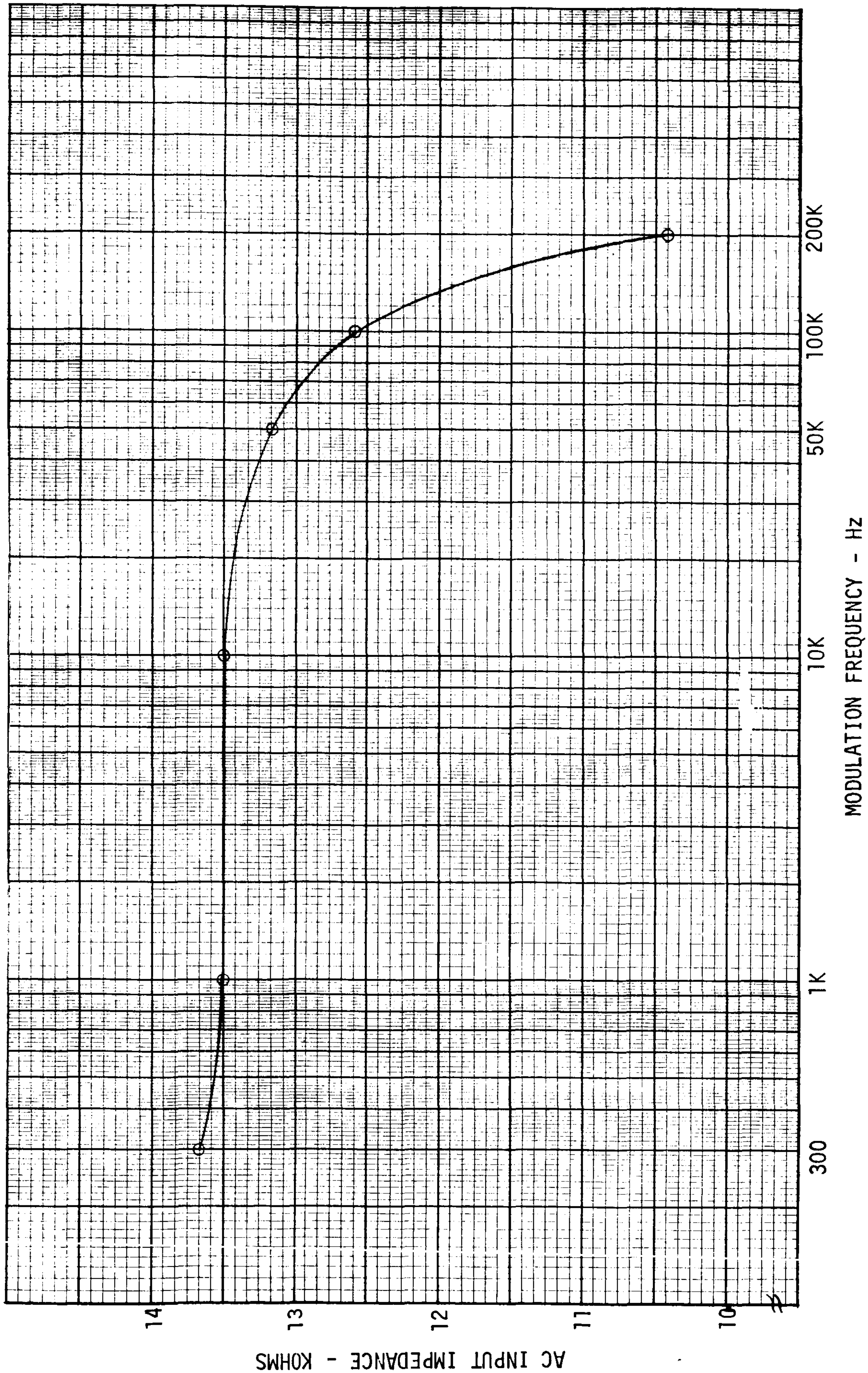


FIGURE 2-3

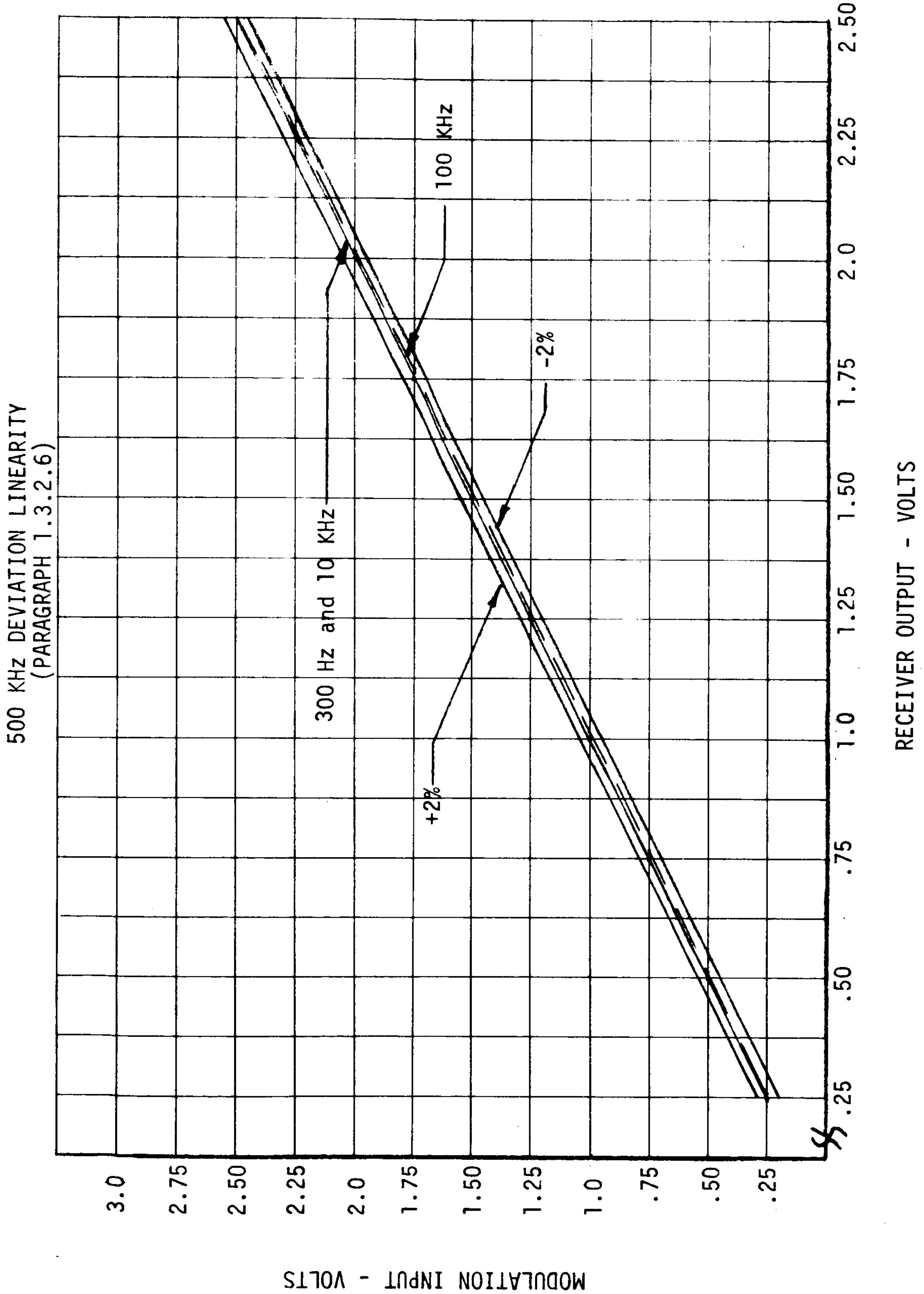

500 KHz DEVIATION LINEARITY
(PARAGRAPH 1.3.2.6)
300 Hz and 10 KHz
100 KHz
-2%
+2%
RECEIVER OUTPUT - VOLTS
.25
.50
.75
1.0
1.25
1.50
1.75
2.0
2.25
2.50
MODULATION INPUT - VOLTS
3.0
2.75
2.50
2.25
2.0
1.75
1.50
1.25
1.0
.75
.50
.25

FIGURE 2-4

MODULATION FREQUENCY RESPONSE
(PARAGRAPH 1.3.2.7)

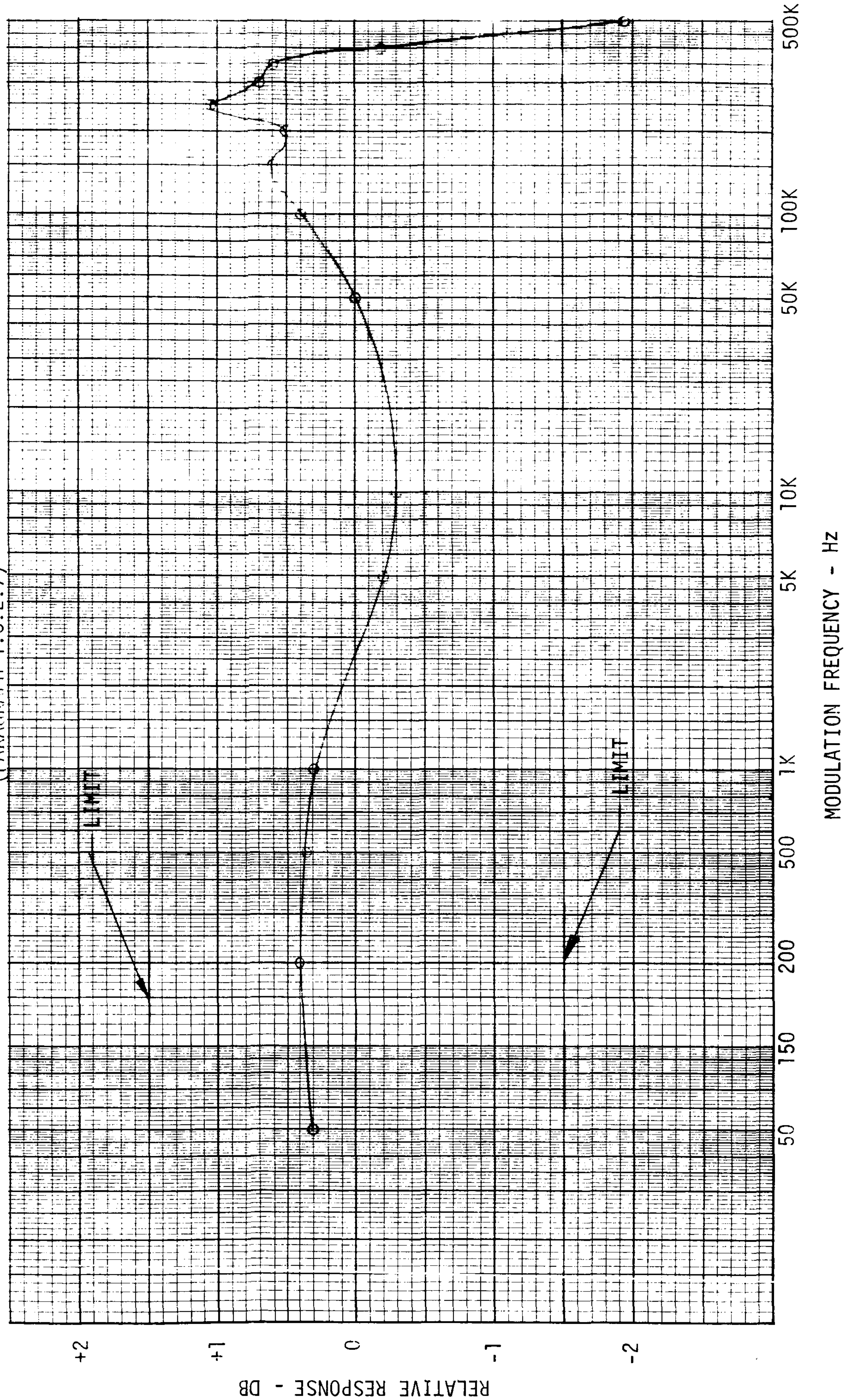


FIGURE 2-5

2.1.10 Modulation Distortion (Test Paragraph 1.3.2.9)

Test data shows the unit satisfied the requirements, however, this data does include the frequency source, and receiver distortion.

2.1.11 Intermodulation Distortion (Test Paragraph 1.3.2.10)

Test data shows the unit satisfied the requirements, however, data also includes test equipment distortion.

2.1.12 Load Impedance

2.1.12.1 VSWR (Test Paragraph 1.3.2.11.1)

During this test frequency and supply input current remained within requirements, however, the output power dropped below the required 20 watts at 28 V (17.9 watt), 32 V (17.4 watt) and 25.5 V (17.9 watt).

2.1.12.2 Open Circuit (Test Paragraph 1.3.2.11.2)

The units performance was essentially unchanged by this test. Power output, supply current and frequency were within requirement both before and after the open circuit period.

2.1.12.3 Short Circuit (Test Paragraph 1.3.2.11.3)

The units performance was essentially unchanged by this test, however, before the start of the test period the output power was 19.8 watts, slightly below the 20 watt requirement, after the test the power output was 20.1 watts. Frequency and supply current were within requirement before and after the test period.

2.1.13 Incidental Amplitude Modulation (Test Paragraph 1.3.2.12)

Incidental AM was within requirements.

2.1.14 Miscellaneous Tests

2.1.14.1 Automatic Level Control Performance

A test was conducted to determine the performance of the automatic level control circuit, the results are shown in Figure 2-6. This test was conducted by engineering during final assembly of the transmitter.

2.1.14.2 Supply Voltage Levels

During final assembly supply voltage levels within the transmitter assembly were measured. A voltage drop of approximately one volt was measured between the input connector and the power amplifier input connection. This voltage drop was found to be almost entirely due to the reverse voltage protection diode used in series with the input line. Thus with a

AUTOMATIC LEVEL CONTROL PERFORMANCE

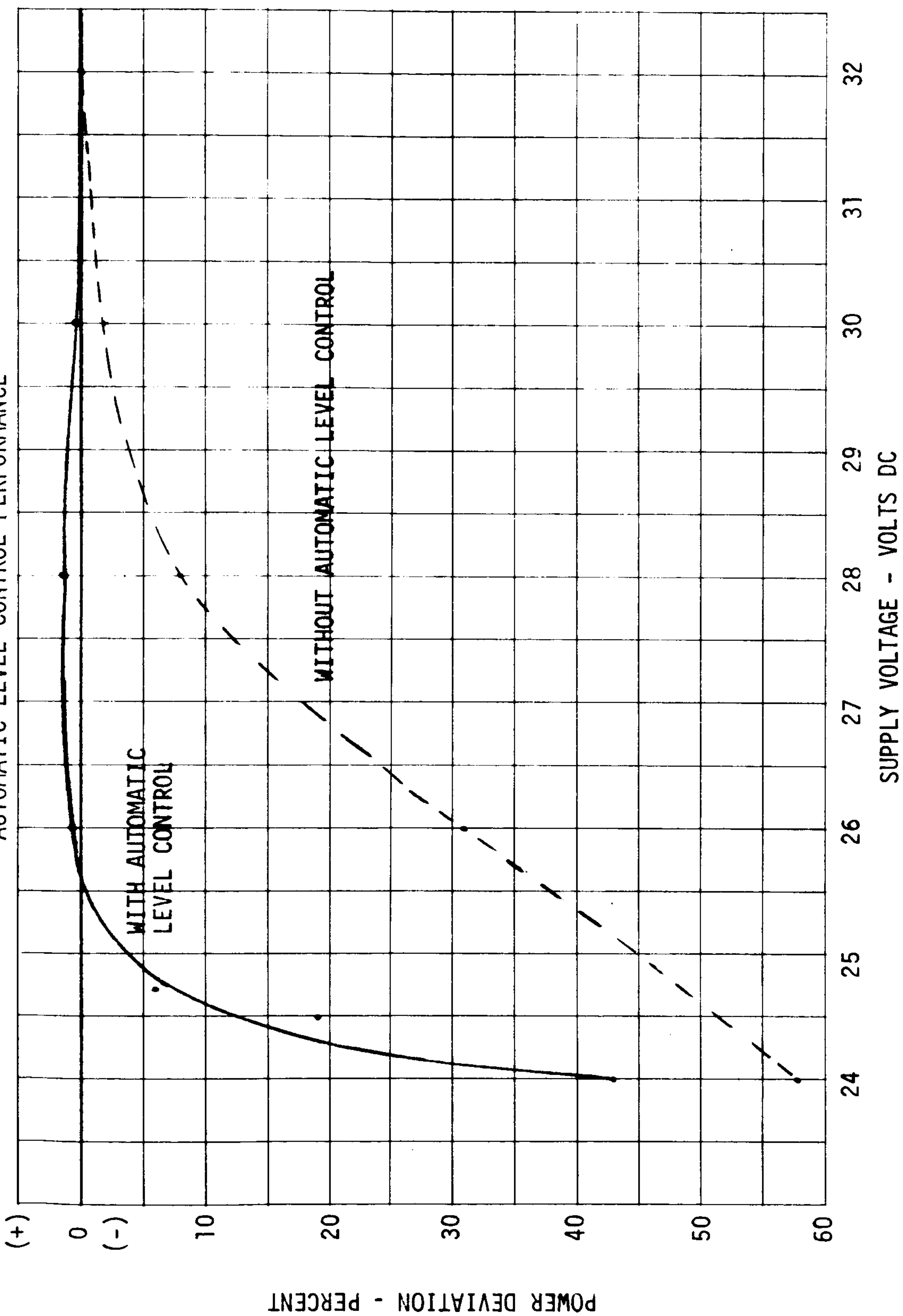


FIGURE 2-6

2.1.14.2 (Continued)

24 volt input only 23 volts are available to the power amplifier and pre-driver/driver. At this voltage level these modules apparently have insufficient gain to maintain the required output power.

2.14.3 Radio Frequency Interference

A brief audio frequency conducted, (powerline) susceptibility test was made by engineering. The unit was found to be susceptible to audio signals, in that incidental FM and AM increased and the power output decreased. Review of the test setup which was to be in accordance with Figure 17 of MIL-I-6181D, indicates the 400 MFD capacitor was omitted from the DC power source, this capacitor would probably have reduced the susceptibility somewhat. The unit was expected to be susceptible to this test in that the RFI module design had been only to contain and suppress internal signals. In view of the 1 volt drop from the input connector to the power amplifier it was not considered desirable to incorporate additional filtering until some tests had been conducted.

PART NO.	SERIAL NO. OR LOT NO.	ORDER NO.	BOEING LAUNCH SYSTEMS BRANCH RECORDS SYSTEM S-812-65-33 REV. 2/65	PAGE 1 OF 10

DATA SHEET

		RESULTS	CHECK DATE & SHOP	CHECK DATE & INSP.	CHECK DATE & CUST.
1.3.2.1	TEST SETUP				
1.3.2.1	Power Ground - Chassis Ground	>500 meg/ohm			
	Input Signal Ground - Chassis Ground	>500 meg/ohm			
	Power Ground - Input Signal Ground	100 meg/ohm			
1.3.2.3	WARM-UP TIME				
	@ 3 Minutes Power Output	21.6 Watts			
	Output Frequency	2277.576275			
	@ 6 Minutes Power Output	22.8 Watts			
	Output Frequency	.2277.579453			
	@ 9 Minutes Power Output	22.8 Watts			
	Output Frequency	2277.581454			

PAGE	PART NO.	NOMENCLATURE	SERIAL NO. OR LOT NO.	ORDER NO.
1 OF 10	SK/LST0490-1D	20 Watt Transmitter		

TABLE 2-I TEST DATA

PART NO.	SERIAL NO. OR LOT NO.	ORDER NO.	BOEING LAUNCH SYSTEMS BRANCH RECORDS SYSTEM S-812-65-33 REV. 2/65	PAGE 2 OF 10

DATA SHEET

			RESULTS	CHECK DATE & SHOP	DATE & INSP.	DATE & CUST.
1.3.2.2	The adjustable attenuation is set to indicate a reading of 34.75 DB below the true output power.					
	Supply Voltage @ 28 VDC	Current	7.15 amp			
		Frequency	2277.563628			
		Power 0.675	20.25 Watt			
		Efficiency	10.1%			
	Supply Voltage @ 32 VDC	Current	7.10 amp			
		Frequency	2277.564731			
		Power 0.678	20.35 Watt			
		Efficiency	8.95%			
	Supply Voltage @ 25 VDC	Current	7.3 amp			
		Frequency	2277.562355			
		Power 0.560	16.80 Watt			
		Efficiency	9.22%			
1.3.2.4	Input Impedance					
1.3.2.4.1	DC Input Impedance		13.2 Kohms			

PAGE 2 OF 10	PART NO.	NOMENCLATURE	SERIAL NO. OR LOT NO.	ORDER NO.
	SK/LST0490-1D	20 Watt Transmitter		

PART NO.	SERIAL NO. OR LOT NO.	ORDER NO.	BOEING LAUNCH SYSTEMS BRANCH RECORDS SYSTEM S-812-65-33 REV. 2/65	PAGE 3 OF 10

DATA SHEET

				RESULTS	CHECK DATE & SHOP	CHECK DATE & INSP.	CHECK DATE & CUST.
1.3.2.4.2	AC Input Impedance						
		@ 300 Hz		13.7 Kohms			
		@ 1 KHz		13.5 Kohms			
		@ 10 KHz		13.5 Kohms			
		@ 50 KHz		13.2 Kohms			
		@ 100 KHz		12.6 Kohms			
		@ 200 KHz		10.4 Kohms			
1.3.2.5	Deviation Sensitivity						
1.3.2.5.1	AC Sensitivity						
		@ 28 VDC					
			Modulation Input Voltage	0.49 VAC			
			Deviation Sensitivity	204 KHz/Volt			
		@ 32 VDC					
			Modulation Input Voltage	0.49 VAC			
			Deviation Sensitivity	204 KHz/Volt			
		@ 25 VDC					
			Modulation Input Voltage	0.495 VAC			
			Deviation Sensitivity	202 KHz/Volt			
1.3.2.5.2	DC Sensitivity						
		@ 28 VDC	+1.0 VDC	2277.703954			
			-1.0 VDC	2277.423222			
		@ 32 VDC	+1.0 VDC	2277.704958			
			-1.0 VDC	2277.424371			
		@ 25.5 VDC	+1.0 VDC	2277.702822			
			-1.0 VDC	2277.422117			

PAGE 3 OF 10	PART NO.	NOMENCLATURE	SERIAL NO. OR LOT NO.	ORDER NO.
	SK/LST0490-1D	20 Watt Transmitter		

PART NO.	SERIAL NO. OR LOT NO.	ORDER NO.	BOEING LAUNCH SYSTEMS BRANCH RECORDS SYSTEM S-812-65-33 REV. 2/65	PAGE 4 OF 10

DATA SHEET

		Modulation Input Vi	RESULTS	CHECK DATE & SHOP	CHECK DATE & INSP.	CHECK DATE & CUST.
1.3.2.6 AC Deviation Linearity						
@ 300 Hz			Video Output			
		0.250 VDC	0.249 VDC			
125 Khz Deviation @ 300 Hz = 0.16%		0.500 VDC	0.498 VDC			
		0.625 VDC	0.625 VDC			
500 KHz Deviation @ 300 Hz = 0.25%		0.750 VDC	0.750 VDC			
		1.000 VDC	0.999 VDC			
		1.250 VDC	1.248 VDC			
		1.500 VDC	1.501 VDC			
		1.750 VDC	1.751 VDC			
		2.000 VDC	2.003 VDC			
		2.250 VDC	2.255 VDC			
		2.500 VDC	2.500 VDC			
@ 10KHz						
		0.250 VDC	0.250 VDC			
125 KHz Deviation @ 10 KHz = 0.08%		0.500 VDC	0.499 VDC			
		0.625 VDC	0.623 VDC			
500 KHz Deviation @ 10 KHz = 0.312%		0.750 VDC	0.746 VDC			
		1.000 VDC	0.996 VDC			
		1.250 VDC	1.252 VDC			
		1.500 VDC	1.498 VDC			
@ 10 KHz		1.750 VDC	1.754 VDC			
		2.000 VDC	2.006 VDC			
		2.250 VDC	2.252 VDC			
		2.500 VDC	2.502 VDC			
@ 100 KHz						
		0.250 VDC	0.258 VDC			
125 KHz Deviation @ 100 KHz = 0.08%		0.500 VDC	0.513 VDC			
		0.625 VDC	0.639 VDC			
500 KHz Deviation @ 100 KHz = 0.36%		0.750 VDC	0.765 VDC			
		1.000 VDC	1.014 VDC			
		1.250 VDC	1.270 VDC			
		1.500 VDC	1.524 VDC			
		1.750 VDC	1.772 VDC			
		2.000 VDC	2.016 VDC			

PAGE 4 OF 10	PART NO.	NOMENCLATURE	SERIAL NO. OR LOT NO.	ORDER NO.
	SK/LST0490-1D	20 Watt Transmitter		

PART NO.	SERIAL NO. OR LOT NO.	ORDER NO.	BOEING LAUNCH SYSTEMS BRANCH RECORDS SYSTEM S-812-65-33 REV. 2/65	PAGE 5 OF 10

DATA SHEET

	RESULTS	CHECK DATE & SHOP	CHECK DATE & INSP.	CHECK DATE & CUST.
1.3.2.6 (Continued)				
2.250 VDC 2.500 VDC	2.259 VDC 2.500 VDC			

PAGE 5 OF 10	PART NO.	NOMENCLATURE	SERIAL NO. OR LOT NO.	ORDER NO.
	SK/LST0490-1D	20 Watt Transmitter		

PART NO.	SERIAL NO. OR LOT NO.	ORDER NO.	BOEING LAUNCH SYSTEMS BRANCH RECORDS SYSTEM S-812-65-33 REV. 2/65	PAGE 6 OF 10

DATA SHEET

			RESULTS		CHECK DATE & SHOP	DATE & INSP.	DATE & CUST.
1.3.2.7	Frequency Response						
			Rcvr Output	DB			
	Receiver Tuning Offset -0-	50 Hz	1.033	+0.3			
	Video Filtering 1000 KHz	200 Hz	1.043	+0.4			
	If Bandwidth 3-3 Mc	500 Hz	1.040	+0.35			
	Microvolt Level 100 K4	1 KHz	1.032	+0.3			
		5 KHz	0.975	-0.2			
		10 KHz	0.968	-0.3			
	Reference Point	50 KHz	1.000	0.0			
		100 KHz	1.046	+0.4			
		150 KHz	1.073	+0.6			
		200 KHz	1.064	+0.5			
		250 KHz	1.113	+1.05			
		300 KHz	1.089	+0.7			
		350 KHz	1.065	+0.6			
		400 KHz	0.975	-0.2			
		450 KHz	0.885	-1.1			
		500 KHz	0.796	-1.95			
1.3.2.8	Incidental Frequency Modulation						
	Peak-to-Peak Deviation		6.4 KHz				
	Video Bandwidth		500 KHz				
	Receiver Input Signal Level		100 K Microvolts				

PAGE 6 OF 10	PART NO.	NOMENCLATURE	SERIAL NO. OR LOT NO.	ORDER NO.
	SK/LST0490-1D	20 Watt Transmitter		

PART NO.	SERIAL NO. OR LOT NO.	ORDER NO.	BOEING LAUNCH SYSTEMS BRANCH RECORDS SYSTEM S-812-65-33 REV. 2/65	PAGE 7 OF 10

DATA SHEET

	RESULTS	CHECK DATE & SHOP	CHECK DATE & INSP.	CHECK DATE & CUST.
1.3.2.9 Modulation Distortion				
@ 5 KHz Fundamental Modulating Frequency	DB			
Second Harmonic	-39.0			
Third Harmonic	-46.0			
@ 10 KHz Fundamental Modulating Frequency				
Second Harmonic	-39.0			
Third Harmonic	-45.5			
@ 25 KHz Fundamental Modulating Frequency				
Second Harmonic	-40.5			
Third Harmonic	-45.5			
@ 50 KHz Fundamental Modulating Frequency				
Second Harmonic	-39.5			
Third Harmonic	-47.0			
@ 100 KHz Fundamental Modulating Frequency				
Second Harmonic	-40.0			
Third Harmonic	-47.0			

PAGE 7 OF 10	PART NO.	NOMENCLATURE	SERIAL NO. OR LOT NO.	ORDER NO.
	SK/LST0490-1D	20 Watt Transmitter		

PART NO.	SERIAL NO. OR LOT NO.	ORDER NO.	BOEING LAUNCH SYSTEMS BRANCH RECORDS SYSTEM S-812-65-33 REV. 2/65	PAGE 8 OF 10

DATA SHEET

		RESULTS	CHECK DATE & SHOP	CHECK DATE & INSP.	CHECK DATE & CUST.
1.3.2.10 Intermodulation Distortion					
Table I					
Combination #1	Sum	-40.0 DB			
	Difference	-40.0 DB			
Combination #2	Sum	-40.5 DB			
	Difference	-40.0 DB			
Combination #3	Sum	-41.1 DB			
	Difference	-41.0 DB			
Combination #4	Sum	-40.5 DB			
	Difference	-42.0 DB			

PAGE	PART NO.	NOMENCLATURE	SERIAL NO. OR LOT NO.	ORDER NO.
8 OF 10	SK/LST0490-1D	20 Watt Transmitter		

PART NO.	SERIAL NO. OR LOT NO.	ORDER NO.	BOEING LAUNCH SYSTEMS BRANCH RECORDS SYSTEM S-812-65-33 REV. 2/65	PAGE 9 OF 10

DATA SHEET

			RESULTS	CHECK DATE & SHOP	DATE & INSP.	DATE & CUST.
1.3.2.11	Load Impedance					
1.3.2.11.1	1.8 VSWR					
	@ 28 VDC	Supply Current Output Power Output Frequency	7.4 amp 17.9 Watt 2277.576128			
	@ 32 VDC	Supply Current Output Power Output Frequency	7.3 amp 17.4 Watt 2277.577756			
	@ 25.5 VDC	Supply Current Output Power Output Frequency	7.75 amp 17.9 Watt 2277.575898			
1.3.2.11.2	Open Circuit					
	Before 50 ohm load disconnected	Output Power Supply Current Carrier Frequency	20.4 Watt 7.15 amp 2277.563892			
	With 50 ohm load reconnected	Output Power Supply Current Carrier Frequency	20.1 Watt 7.05 amp 2277.564077			

PAGE 9 OF 10	PART NO.	NOMENCLATURE	SERIAL NO. OR LOT NO.	ORDER NO.
	SK/LST0490-1D	20 Watt Transmitter		

PART NO.	SERIAL NO. OR LOT NO.	ORDER NO.	BOEING LAUNCH SYSTEMS BRANCH RECORDS SYSTEM S-812-65-33 REV. 2/65	PAGE 10 OF 10

DATA SHEET

			RESULTS	CHECK DATE & SHOP	DATE & INSP.	DATE & CUST.
1.3.2.11.3	Short Circuit					
	Initial Configuration					
		Output Power	19.8 Watts			
		Supply Current	7.05 amp			
		Carrier Frequency	2277.563989			
	After Short					
		Output Power	20.1 Watt			
		Output Frequency	2277.563881			
		Supply Current	7.1 amp			
1.3.2.12	Incidental amplitude Modulation					
1.3.2.12 (h)		Peak-to-Peak	0.5%			
1.3.2.12 (i)		Peak-to-Peak	2.5%			

PAGE	PART NO.	NOMENCLATURE	SERIAL NO. OR LOT NO.	ORDER NO.
10 OF 10	SK/LST0490-1D	20 Watt Transmitter		

PART NUMBER	SERIAL NO. OR LOT NO.	ORDER NO.	BOEING LAUNCH SYSTEMS RECORDS SYSTEM S-812-65-32 REV. 2 65

TEST EQUIPMENT CONFIGURATION LOG

PART NUMBER	ENGR. CONFIG.	NOMENCLATURE	SERIAL NO.	CALIBRATION LAST	CALIBRATION DUE	UNPLANNED EVENT S/N	DATE & SHOP	DATE & INSP.	DATE & CUST.
777D	-	Directional Coup	01624	Apr. 1967	Apr. 1968				
874 GAL	-	Adjustable Attenuator	N/A						
394 A	-	Variable Attenuator	1204	Jan. 1968	Jan. 1969				
1600-100 FM	-	Coaxial Termination	388	June 1967	June 1968				
8614A	-	Signal Generator	34300248	Feb. 1968	Aug. 1968				
431 C	-	Power Meter	618-01202	Oct. 1967	Apr. 1968				
M36-10A	-	Power Supply	11075 H	Dec. 1967	May 1968				
428B	-	Ammeter	13102172	Jan. 1968	Apr. 1968				
3440A	-	Digital Voltmeter	53T249	Jan. 1968	July 1968				
3443A	-	High Gain Audio Range Watt	531247	Jan. 1968	July 1968				
5245L	-	Electronic Counter	430-01899	Feb. 1968	May 1968				
5254A	-	Frequency Converter	42900154	Jan. 1968	May 1968				
HR40-750	-	Power Supply	2T758E	Jan. 1968	July 1968				
1432-M	-	Decade Resistor	20322	Nov. 1967	May 1968				
650A		Test Oscillator	3311290	Oct. 1967	Apr. 1968				
400E		Voltmeter	536-02651	Jan 1968	Apr. 1968				

PAGE 1 OF 3	PART NUMBER	NOMENCLATURE	SERIAL NO. OR LOT NO.
	SYLST0480-1D	20 Watt Transmitter	

TABLE 2-II TEST EQUIPMENT

TEST EQUIPMENT CONFIGURATION LOG

PART NUMBER	ENGR. CONFIG.	NOMENCLATURE	SERIAL NO.	CALIBRATION LAST	CALIBRATION DUE	UNPLANNED EVENTS N	DATE & SHOP	DATE & INSP.	DATE & CUST.
457A	-	AC/DC Converter	017431	Feb. 1968	Apr. 1968				
R1037A	-	Receiver	474	Jan. 1968	Jan. 1968				
RFT106A	-	RF Tuner	128	Nov. 1967	May 1968				
3.3 MC FSD	-	Pluging Filter	123	Jan. 1968	July 1968				
1037	-	Counter	555	Jan. 1968	May 1968				
SPA-4A	-	Spectrum Analyzer	91	Feb. 1968	Apr. 1968				
1432P	-	Decade Resistor	35292	Oct. 1967	Apr. 1968				
400R	-	AC Voltmeter	536-0/230	Feb. 1968	May 1968				
302A	-	Wave Analyzer	437-04143	Jan. 1968	May 1968				
310A	-	Wave Analyzer	415-00733	Nov. 1967	May 1968				
65A	-	Oscillator	233-12851	Nov. 1967	March 29, 1968				
431B	-	Power Meter	310-10282	Oct. 1967	Apr. 1968				
478A	-	Thermister Mount	3748	Sept. 1967	Sept. 1968				
545B		Oscilloscopic	000799	March 1968	July 1968				
Type CA		Plug-IN Unit	009872	Feb. 1968	July 1968				
XD-6A		Detector	041265	N/A	N/A				

PAGE 2 OF 3	PART NUMBER	NOMENCLATURE	SERIAL NO.
	SK/LS10490-1D	20 Watt Transmitter	

TEST EQUIPMENT CONFIGURATION LOG

PART NUMBER	ENGR. CONFIG.	NOMENCLATURE	SERIAL NO.	CALIBRATION LAST	CALIBRATION DUE	UNPLANNED EVENT S N	DATE & SHOP	DATE & INSP.	DATE & CUST.
478A	-	Thermister Mount	13448	June 1967	June 1968				
874LBA	-	Slotted Line	BC591739	Aug. 1967	Aug. 1968				
874D20L	-	ADJ. STUB	NAS48279	Jan. 1968	July 1968				

PAGE	PART NUMBER	NOMENCLATURE	SERIAL NO. OF	ORDER NUMBER
3				

SECTION 3

CONCLUSIONS AND RECOMMENDATIONS

3.0 CONCLUSIONS

3.1 GENERAL

Based on the tests conducted, it can be concluded that the performance of the transmitter is within tolerance except for the low power output at the lower supply voltage, low efficiency, and the line conducted audio interference.

3.1.1 Power Output

The low power output of the transmitter at the lower supply voltages was the result of a number of conditions which are as follows:

a. The excessive voltage drop between the transmitter input and the predriver/driver and power amplifier (greater than one volt).

b. Insufficient gain of the predriver/driver and power amplifier.

c. The change in output impedance of the power amplifier with changes in supply voltage.

d. The impedance mismatch between the power amplifier and the first tripler.

e. Changes in the dc output of the ALC detector circuit with changes in supply voltage.

The system was originally designed to have sufficient gain at 23.5 volts but there was some degradation in this gain when the system was totally assembled. This degradation was mostly due to the inability to obtain a good impedance match between the power amplifier and the first tripler. The improper impedance match not only resulted in lower power transfer but also considerably distorted the waveshape of the signal at the output of the power amplifier. Because the output impedance of the power amplifier varied with changes in line voltage, the impedance match between the two modules also changed. This condition not only causes changes in the power transfer characteristics but also had an adverse effect on the output of the ALC detector circuit.

The ALC detector at the output of the power amplifier consists of an inductive dividing network, isolation capacitors and a detector diode. The dc voltage out of the detector varies in proportion to the peak input voltage. The input voltage for the detector in this system is considerably distorted and contains a large amount of second and third harmonic due to the impedance mismatch of the first tripler. The amount of harmonic distortion in the detector input signal varies as the supply voltage is changed due to the changing output impedance of the power amplifier. The overall result of this situation is that the dc output

3.1.1 (Continued)

voltage of the detector does not remain constant for a fixed power outpout of the power amplifier as the supply voltage is varied, nor is this detected output voltage exactly linear with respect to changes in power amplifier output power because of the same impedance mismatch.

The major causes of the low transmitter output power were due to the lower than anticipated voltage at the predriver/driver and power amplifier and the impedance mismatch between the power amplifier and the first tripler. To correct this situation, it may be possible to re-adjust the predriver/driver and power amplifier circuits to obtain sufficient output power with a supply voltage of approximately 22.5 volts. If sufficient power cannot be obtained, and additional stage of amplification may be required in the predriver/driver circuit. It may also be possible to reduce the voltage drop between the supply input to the transmitter and the two amplifier modules by using two reverse polarity protection diodes in parallel or by incorporating a different type protection system.

Component changes will be required in the input circuit of the first tripler in order to obtain an improved impedance match with power amplifier. Some redesign of the first tripler input and idler circuits may be required to obtain an acceptable matching capability.

An improved impedance match between the power amplifier and first tripler should improve the ALC performance. If a problem still exists, the sampling point of the ALC detector could be moved to the output of the third tripler power adder where there is very little distortion present in the waveform.

3.1.2 Efficiency

Some degradation in the dc to rf efficiency of the transmitter was caused by impedance mismatches between modules and non-optimum tuning of the modules, especially the frequency multipliers.

As previously discussed, the impedance mismatch between the power amplifier and the first tripler caused some loss in power transfer between these two circuits. There was also some degradation in performance of the third tripler and the impedance match between the second and third tripler.

Considerable effort was expended in obtaining the required performance of the third tripler. The varactors which were used in the original design of this tripler were pre-production units. When the manufacturer went into full production of this device small changes were made in the manufacturing process. These small changes had an adverse effect on the operation of the device in this particular circuit. The problem was not so much in obtaining the required efficiency of the units operating separately, but more in obtaining the proper operation of the units in

3.1.2 (Continued)

parallel with the power splitter and power adder. It appears that some slight change in the parameters of the varactor caused a change in the input and/or output impedance of the circuit. With some additional design effort, the circuit could be characterized for this new device and higher efficiency obtained.

However, it is difficult to say what improvement in efficiency could be achieved from these improvements in impedance matching. At the most, the improvements would yield no more than a one per cent overall increase in the transmitter dc to rf efficiency. What would result from these improved impedance matches would be an additional power output capability of two to three watts.

3.1.3 Line Conducted, Audio Susceptibility (RFI)

The transmitter was very susceptible to line conducted audio frequencies. The three volt (rms) signal which was superimposed on the power supply line created considerable degradation in the system performance. The degradation in performance was evident in gross measurements of incidental AM and FM and the spurious signals contained in the output spectrum. The degradation increased as the frequency of the audio signal was increased.

About the only solution to this problem would be additional filtering of the supply voltage at the input to the transmitter. This would require the adding of series inductance and shunt capacitance to the RFI filter of the transmitter. The inductance would cause some increase in the dc voltage drop of the transmitter supply thereby requiring improved performance of the predriver/driver and power amplifier. It may be possible to improve the frequency response of the ALC circuit and enable it to compensate for some of the lower frequency interference.

3.1.3 Environmental Conditions

The transmitter was not subjected to any extreme environmental conditions. Because of this, it is quite uncertain how the transmitter will perform under certain adverse conditions such as high temperature and vibration. High temperatures would cause some decrease in power output and the dc to rf efficiency of the transmitter. All components were selected to withstand the high temperature enviornments. However, due to the degradation in efficiency of this transmitter, there is not too great a safety margin for some of the components. The suggestions for improving the efficiency and power output of the transmitter which have been discussed previously, would enable the transmitter to operate safely at the elevated temperatures.

The degradation of the transmitter performance due to vibration cannot readily be predicted. Some test modules have been subjected to vibration testing in the past, but the complete transmitter has not. The mechanical

3.1.3 (Continued)

design and packaging of the modules was effected with major concern being given to the vibration requirements of the transmitter.

3.1.4 Spurious Signals

The output frequency spectrum of the transmitter contained some spurious signals , the amplitudes of which were only 60 db down from the peak amplitude of the carrier. However, there were no visible spurious signals when a Hewlett-Packard 608 signal generator was used in place of the exciter/modulator as the transmitter signal source. Nor were there any spurious signals discernible on the output of the exciter/ modulator when it was disconnected from the transmitter and monitored directly with a spectrum analyzer. The spurious signals must therefore be the result of adverse impedance matching or loading conditions of the predriver/driver assembly. There are two possible solutions for this problem. One would be the addition of an impedance matching network at the input of the predriver/driver. The other possible solution would be to add a buffering of emitter follower stage to the exciter/ modulator. The spurious signals could generally be reduced by tuning of the exciter/modulator bandpass filters and output coupling, but they could not be completely eliminated by this procedure.

3.2 RECOMMENDATIONS

The limited tests which have been performed on this transmitter have shown the basic system design to be effective and sound. The test data and the time expended in the development of this transmitter also show that additional circuit design improvements are required before the transmitter can be manufactured in limited quantities on a production basis.

The system design, which has the exciter/modulator operating at a frequency of approximately 84 MHz followed by a power amplifier and a times 27 frequency multiplier, is by no means an ultimate design and can be improved upon as the state-of-the-art in semiconductors advances. It may now be possible, with the recent advances in rf transistor technology, to operate the power amplifier at a frequency of 250 MHz instead of 84 MHz. This change would eliminate the first tripler and some of the associated problems of efficiency and impedance matching.

The higher frequency power amplifier would also allow more optimum frequencies to be selected for the exciter/modulator crystal oscillator and voltage control oscillator with respect to suppression of mixer generated intermodulation products. Some of these intermodulation products may be the source of the spurious signals in the output frequency spectrum of the present transmitter.

The one circuit which limits the operational performance of the transmitter is the third tripler. There is no single varactor on the market

3.2 (Continued)

today capable of handling the power and providing the required efficiency for this circuit. This includes the various R & D devices that the manufacturers are working on at the present time. The most promising types of devices for the future are the new series-chip units that some manufacturers are developing. However, it is estimated that units for application in this transmitter will not be in pilot line production for at least a year.

This then means that two varactors will continue to be required in the third tripler in order to provide the power handling capability.

Using a doubler instead of a tripler in the final frequency multiplier will not improve the overall performance of the system. Two devices will still be required in order to handle the power. Although a doubler is more efficient than a tripler, the doubler will be operating at a higher input frequency which will reduce the efficiency to approximately that of the tripler. Another factor to be considered is that if the final multiplier is a doubler, either the power amplifier will have to operate at a higher frequency or more multiplication stages will be required. The least number of multiplication stages used, the more efficient the system will be.

The third tripler by itself is quite efficient. Efficiencies in excess of 55 percent have been achieved when operating a single device with 25 watts of drive power. Degrading of the third tripler occurs when the two triplers are mated together in the parallel configuration with the power splitter and power adder. Some power is lost in the splitter and adder, plus power is lost due to detuning of the triplers. It is quite possible that the third tripler performance could be significantly improved by operating the two varactors in a push-pull configuration. This could be accomplished with either coaxial cavities or microwave stripline techniques.

Another possible improvement in the system would be to incorporate with either the third tripler or the bandpass filter a detector to sense reflected power of the transmitter output. This detector voltage could be used with the present ALC circuit to protect the transmitter from a high VSWR at the transmitter output. The need for an isolator would then be eliminated and approximately a one watt increase in power output could be realized.

Any one of the preceding recommendations by itself does not offer any great improvement in the overall transmitter performance. However, if each were to be incorporated into the transmitter an overall improvement of several watts could be expected in the power output capability of the transmitter. This would result in a power output capability of approximately 30 watts for a transmitter which is tuned to optimum. A limited production transmitter with a minimum output of 20 watts for all environmental conditions may then be possible.

3.2 (Continued)

The main problem with the present transmitter is that every module must be turned and adjusted for optimum performance in order to approach the minimum requirements of the transmitter. It is almost a certainty that the present transmitter could meet all of the required performance characteristics if its power output were limited to 15 watts.

Although the performance of this transmitter has fallen short of some of the design goals, its development has substantially advanced the power output and frequency range of solid state transmitters. The development has also proven that the basic system design is sound and the overall performance of the transmitter can be improved to meet the design goals with some modification of the basic circuits.